Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

VI. *Part of a Letter from Mr.* Michael Topping, *to Mr.* Tiberius Cavallo, *F.R.S.*

Read February 16, 1792.

DEAR SIR, *Madras, February* 4, 1789.

I INCLOSE you an account of a base line I have measured for a series of triangles I am carrying down the coast of Coromandel. I have already extended them to about 300 miles from Madras, and am upon returning back to prosecute the work quite down to Cape Comorin. The angles are all taken with my Hadley's sextant, made by STANCLIFFE, by means of three tall signals I have constructed of bamboos, 80 feet high, 60 of which I mount upon steps, so as to see (over all trees, &c.) very distinctly my two other signals, at the distance of from 8 to 13 miles. It is, I believe, the first time the Hadley was ever made use of for a purpose of such magnitude; but it is fully equal to it—nay, it does more—the sun's bearing, or oblique distance, from my signals is also taken by it; by which, and his azimuth (computed) I obtain the angles made by them with the meridian; and by combining the whole, the difference of latitude, and meridional distance of every one of them in English fathoms. This is found so nicely, that a mean of my astronomical observations for the latitudes, never differs more than a few seconds from those given by the geometrical mensuration. In all the operations I have had no one to assist me,

except a party of black fellows to carry my flags. I need not tell you how many thousand miles I have travelled to take the angles; nor what the labour and fatigue of such a work must be in this burning climate, where I have frequently had the thermometer at 106° in my tent.

(Signed) M. TOPPING.

An Account of the Measurement of a Base Line *upon the Sea Beach, near* Porto Novo, *on the* Coast of Coromandel, *in May,* 1788; *by Mr.* Michael Topping.

As a necessary foundation for the chain of triangles now carrying on, I have, for some time past, had my thoughts bent towards measuring, with all possible accuracy, a *base line*. This base line, could I have chosen its situation, should have been determined as near the middle of the line of coast I am surveying as possible; but circumstances have not permitted me to make unrestrained choice of its place. On my arrival at Cuddalore, I was told that, as I proceeded southward, I should meet with frequent rivers, and other water courses, that would certainly obstruct me in the design I had formed of measuring it on the sea beach, farther south; and, soon after my removal from that place, I found, with much satisfaction, that the coast, between Cuddalore river and Porto Novo, would serve my purpose extremely well. The beach hereabouts is flat, broad, and remarkably smooth; the only specious objection that can be made to it, is its not being straight, but forming a curved line, concave towards the sea. This, however, I knew to be, in reality, of no bad consequence, since several right

lines of sufficient length might, I perceived, be measured upon it; the angles they might interchangeably make, be taken; and the whole afterwards be reduced to one direct line by calculation.

These considerations, and an accident that, about the same time, befel one of my signals, and delayed my trigonometrical progress, finally determined me to measure my base at this opportunity; and I accordingly began that work by placing two of my large signals, at the distance (as nearly as I could judge) of seven miles asunder, for the terms or extremities of it.

In traversing the coast between the signals, I found that, in order to continue my operations throughout upon the most advantageous part of the beach, I must divide the whole distance into six distinct portions, each portion forming a large angle with the next portion to it: and this I immediately did, by placing five lesser flags, at intervals convenient for that purpose.

I now began my measurement, in prosecuting which I spared neither pains nor care. The two rods, of 25 feet each, which I had provided for this use, had been strictly examined while I was at Cuddalore, and their lengths ascertained, as exactly as the conveniences this country affords would admit of. They had been left *purposely* a little too long, as I found it easier to determine, and allow for such excess, than to reduce them to sufficient exactness. In settling their respective lengths, a capital two-feet brass sector, by ADAMS, was made use of, as a standard: this instrument was not only the best authority I could procure; but, being my own property, would, I considered, be ready for an examination, should an opportu-

nity arise of comparing it, in future, with any measure of more acknowledged credit. The thermometer stood at 87°, when the rods were adjusted by it.

The stands, which I had prepared for levelling the rods, were also brought out; and it was with much regret that I found I could not profit by them, as I had hoped to do, assisted as I was by none but black people, in whom, I perceived, it would have been impossible, without incurring great loss of time, to have impressed a necessary idea of their nature and management. I therefore resolved to dispense with the stands, and to lay the rods, end to end, upon the ground. It was in a similar way that the base line for a series of triangles, continued throughout France, was measured. The French rods, which were nearly of the same length and construction with mine, were disposed, in the very same manner, upon the rugged pavement of a highway near Paris; so that I have every reason to believe the opportunity here afforded me, of a peculiarly level and sandy beach, to be the best of the two.

The mode of conducting the measurement was this:—Staves were first set up, in a direct line, between the flags; from every two of these staves a rope was occasionally stretched, as tight as possible, on the ground, and the rods were laid by the side of the rope. The first rod being properly placed, the second was laid *near its end*, and then very carefully adjusted, so as to touch the ferrule of the other, by a man, who had no other employment to engage his attention; and in the performance of this office he was closely watched by myself. The ferrules, which were of thick brass, had been rounded, not only to make the contact more visible, but because the length of each rod was determined, by their having the spherical figure, more

easily. At the placing of every *second* rod, which was painted white to distinguish it from the other, I registered its number myself in a book, ruled purposely with columns, each column containing ten numbers: my writer did the same in another book: besides which, an attendant, who was furnished with ten small sticks, gave the Tindal, who also assisted in keeping the reckoning, one of them every time the white rod was laid down; and each man made his separate report to me every tenth number. By these precautions, almost all possibility of a mis-reckoning was prevented; and we accordingly found no disagreement throughout. The whole distance was afterwards re-measured, and gave correctly the same number of rods.

At the conclusion of each several measurement, that I might know exactly where to resume it, a stake, three or four feet long, was driven into the ground, till its head became even with the surface. On the top of this stake the but of the last rod was laid; and a line drawn across it with a pointed instrument, shewed precisely where to re-commence the work. The heads of these stakes served likewise as fixed marks on which, at any time, to place the five smaller flags, or the instrument for taking the requisite angles.

The sum of the six measured lines amounted, by the first trial, to *seven hundred double rods, twenty feet six inches and a half*; and by the second, to *seven hundred double rods, twenty-two feet eleven inches and a half*; their difference being *two feet, four inches and a half*, by which the second measurement exceeded the first. The shortest of these measures is made use of, as operations of this nature have always a tendency to excess, rather than deficiency.

Besides this *linear measurement*, seven essential angles were taken (each angle several times over, for security) with an excellent theodolite by RAMSDEN. These were the angles formed, at each extremity of the base, by the nearest intermediate flag, and the remote signal; and those formed at each intermediate flag, by the nearest flag to it, on each hand.

The nature and purport of all this will be easily understood, by inspecting the accompanying figure, Tab. III. fig. 1. and attending to the following explanation and

DEMONSTRATION.

Let N and S represent the northern and southern signals, placed at each extremity of the base line NS.

Let ABCDE represent the positions of the five intermediate flags, between each of which, including the two signals, the six right lines, before mentioned, were measured.

At each of these points the angle formed by the flag, or signal, on each side of it, was taken with the theodolite: for instance, at A, the angle formed at that point by the northern signal N, and flag B ($177° 24' 40''$); at B, the angle formed by the flags A and C ($176° 23'$); and so on. At each end of the base line, the angle formed by the nearest flag and the distant signal was also taken; *e. g.* at N, the angle SNA, and at S, the angle NSE.

These things being premised, to find the angles the other four lines make with the base line, proceed in the following manner:—Produce the line NA to K; also the line BA to H; and, through the point A, draw FG parallel to NS, the base line. From the points ABCDE let fall perpendiculars upon the base line, meeting it at OPQR and T.

The angles SNA, NAF, GAK, are all equal; for SNA and NAF are alternate angles, formed by a right line falling upon two parallels (Euclid, 29th, 1st): and NAF, GAK, are equal angles, formed by the mutual intersection of two right lines (Euclid, 15th, 1st). For the same reason, the angle NAH is equal to KAB, and HAF to GAB. Now, the obtuse angle NAB, being known (from observation), its supplement is equal to BAK, which, being subtracted from GAK, leaves the angle GAB required; by means of which, and the hypothenuse AB (given by mensuration), we obtain the side AG of the right-angled triangle GAB, by plane trigonometry; for as rad.: cosine $\angle$GAB : : side AB : side AG. This computed side is equal to the opposite side OP of the rectangular parallelogram OPAG, which being added to the side NO of the right-angled triangle ONA (found by the like analogy from the observed angle N, and the measured hypothenuse NA) gives the distance NP on the base line.

Proceeding in like manner, with the last found angle, to find the angles of the remaining triangles, and thence their respective bases, we shall have the sides of the corresponding rectangles; the sum of which sides, taken together, will be the true measure of the base line NS.

Supposing no imperfection in the instrument with which the angles have been taken, and no error (however small) committed in taking the six preceding angles, then the angle XES, obtained by this method, will prove exactly equal to the angle NSE, which may be had by observation. In the present instance their difference amounts to no more than $2' 5''$.

In the example before us, the observed angles are as follow, from which we may easily deduce the remaining ones required:

Angle at N	5° 36′ 30″			Angle at D	178° 37′ 30″		
∠ A	177	24	40	∠ E	177	2	0
∠ B	176	23	0	∠ S	6	53	0
∠ C	178	1	15				

With which proceed thus:

NAB	177° 24′ 40″	
Its supplement —	2 35 20	
from	5 36 30	∠ N
gives	3 1 10	∠ required at A.

ABC	176° 23′ 0″	
	3 37 0	
—	3 1 10	
	0 35 50	∠ required at B.

BCD	178° 1′ 15″
	1 58 45
+	0 35 50
∠ required at C	2 34 35

CDE	178° 37′ 30″
	1 22 30
+	2 34 15
∠ required at D	3 57 5

DES	177° 2′ 0″	
	2 58 0	
+	3 57 5	
	6 55 5	∠ req. at N.

E or S. Diff. only from the observed angle. 2′ 5″

It is immaterial at which end of the base line we begin. In the present case, in order to obtain as great precision as possible, the intermediate angles have been deduced from both ends; those at A and B, from the observation at N; and the remaining ones at C D and E, from that at S. Had, however, this precaution been neglected, the error induced, by deriving the four required angles from either primitive, at N or S, would not have affected the true length of the whole base line more than 0,27 of a foot, or not quite so much as three inches and a quarter.

This method of obtaining the measure of an inaccessible line, where the measured lines every where make small angles with it, is a very accurate one; for though, in oblique triangles, small angles, from the difficulty of taking angles perfectly, are likely to produce considerable errors, in right-angled triangles it is the very reverse; as in them the smaller the angle taken, the more accurate will be the result.

Fig. 1. is not drawn in due proportion, either as to the sides or angles; as, had it been justly delineated, there would not have been sufficient room for the auxiliary lines, and letters of reference. Fig. 2. is protracted by scale and sector, and shews the relative length and bearing of the several measured lines, as well as the direct distance of their farthest extremities, and their position with respect to the meridian.

For distinction sake, the measured hypothenusal lines are drawn thicker than those about them; and the lines which are parallels to the base line are dotted.

Table of the measures, with their corrections, of the six hypothenusal lines.

Note, the error of the rod A was 0,10+ Inch., of B 0,12+ Inch.

Distances and number of double rods between the stations.	Measured lengths in feet, &c.			Corrections; subtractive.			Correct length of each hypothenuse.		
D. Rods. Feet. Inches.	Feet.	Inch.	Dec.	Feet.	Inch.	Dec.	Feet.	Inch.	Dec.
Between N signal and 1st flag 146 9 4	7309	4	0	2	8	1	7306	7	9
Between 1st and 2d flags 170 37 6	8537	6	0	3	1	5	8534	4	5
Between 2d and 3d flags 106 11 6	5311	6	0	1	11	4	5309	6	6
Between 3d and 4th flags 83 10 3	4160	3	0	1	6	4	4158	8	6
Between 4th and 5th flags 93 8 2	4658	2	0	1	8	5	4656	5	5
Between 5th flag and south. signal 100 43 5,7	5043	5	7	1	10	2	5041	7	5
				Total effect of error, 12	10	1+			

Table for computing the R. A. Triangles, and reducing the six measured lines to one rectilinear distance.

Angular points.	Angles.	Correct Hypothenuses.	Logarithms.	Reductions.
At north. signal N	5° 36′ 30″ W^ly.	1st Hypothenuse, Feet. Dec. 7306, 66 NA	9. 9979161 3. 8637189 3. 8616350	Feet. Dec. 7271 68 NO
At 1st flag A	3 1 10 W^ly.	2d Hypothenuse, 8534, 38 AB	9. 9993967 3. 9311720 3. 9305687	8522 53 OP
At 2d flag B	0 35 30 E^ly.	3d Hypothenuse, 5309, 55 BC	9. 9999764 3. 7250577 3. 7250341	5309 26 PQ
At 3d flag C	2 32 30 E^ly.	4th Hypothenuse, 4158, 72 CD	9. 9995725 3. 6189596 3. 6185321	4154 63 QR
At 4th flag D	3 55 0 E^ly.	5th Hypothenuse, 4656, 46 DE	9. 9989845 3. 6680559 3. 6670404	4645 59 RT
At 5th flag. E and south. sig. S	6 53 0 E^ly.	6th Hypothenuse, 5041, 63 ES	9. 9968584 3. 7025710 3. 6994294	5005 29 TS 34908 98 NS

Or 11636 English yards (rejecting the Decimals), or 6 Miles. 4 F. 196 Yards. total length of the *base*.

Observations taken, both with the theodolite, and the Hadley, for determining the position of the base line, with respect to the meridian.

1788.	App. time.	Distance of ☉'s centre from signal observed.	☉'s altitude, centre cor.	☉'s azimuth computed.	Horizontal ∠ between ☉'s centre and signal.	Angle made by signal with meridian.
May	H. ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
24	about 7 A. M.	—	21 52 50	71 59 18	With theodolite, mean of 6 sights, 111 34 0	3 33 18
25	about 7 A. M.	—	19 22 37	71 32 1	mean of 6 68 3 35	3 28 26
27	about 5 P. M.	—	18 45 54	71 3 40	mean of 6 105 26 35	3 29 46
29	about $7\frac{1}{2}$ A. M.	—	29 20 18	71 29 20	mean of 6 111 56 8	3 25 28
29	about $4\frac{1}{2}$ P. M.	—	27 45 41	71 21 34	mean of 6 105 9 28	3 29 6
					mean	3 29 12
29	A. M. 7 18 26	mean of 4 Hadley obs. 110 35 30	computed 22 19 26	71 6 30	computed 112 21 10	3 27 40
29	P. M. 4 27 39	mean of 3 103 42 9	computed 25 35 0	71 17 40	computed 105 13 47	3 28 33
					mean	3 28 6

The mean of 28 observations by the theodolite is -	3° 29′ 12″
The mean of 7 observations with the Hadley is - -	3 28 6
The medium of both is therefore (by which the south end of the base is westerly, and the north end easterly of the meridian) - - -	3 28 39

N. B. The set of observations, taken as above, on the 25th of May, were made at the southern signal; all the rest at the northern signal.

Meridional observations of stars for determining the latitude of each end of the base line.

Stars.	True zenith at south end of base.	Distances at next southern station.	Latitude of south end of base.
β in Centaur -	70° 54′ 3″	—	11° 33′ 34″
α in Centaur -	71 31 19	—	11 33 48
Antares - -	37 30 14	—	11 33 40
α in Centaur -	—	71 27 4	11 33 34
β in Cross - -	—	70 0 50	11 33 2
η in Ursa Major	—	38 53 16	11 33 14
β in Centaur -	—	70 49 11	11 32 43
Antares - -	—	37 25 58	11 33 25
η in Ursa Major	—	38 53 1	11 33 29
β in Centaur -	—	70 50 11	11 33 43
α in Centaur -	—	71 26 58	11 33 27
η in Ursa Major	—	38 53 16	11 33 14
β in Centaur -	—	70 49 26	11 32 58
Mean latitude of south end -			11 33 22
			+ 5 42
Latitude of north end of base line			11 39 4

To settle the position of the base, with respect to the meridian, the sun's bearing from each signal, and his azimuth, were observed several times, both with the theodolite and the Hadley; and, having made the necessary computations, I became satisfied of the justness of an opinion I had before entertained, that the Hadley is by far the best instrument in general practice for such purposes: for though the theodolite has the advantage, from its fixed position, and

the power of its telescope, in taking horizontal angles *upon the horizon*; yet, at any considerable elevation, when a strict attention is required to the vertical adjustments of the theodolite, such attention is incompatible with the nature of a portable instrument, which is ever liable to suffer change in its adjustments by even the most careful removal from place to place.

The table, page 110, gives the results of these observations, and the data from which they were computed. Nothing need be said of the two preceding tables, which sufficiently explain themselves.

The last table contains meridional observations of stars for determining the latitude of each respective termination of the base line. No observations were obtained at the northern extremity, the weather proving uncommonly cloudy while I was there; and only three latitudes were observed at the south end. The others were taken at my next southern station, and reduced to the terms of the base by the adjacent triangles. The difference of latitude between that station and the south end of the base, I found by measurement to be 8201 yards, or 4′ 1″; and the difference of latitude between the terms of the base 5′ 42″. For considering a portion of the meridian passing through either end of the base, as the cosine of an arc, whose radius is 11636 yards, and subtense 3° 28′ 39″, we shall find the difference of latitude to be 11614 yards = 5′ 42″. By a mean of all the astronomical observations, the south end of the base lies in latitude 11° 33′ 22″ N.; the north end consequently lies in latitude 11° 39′ 4″.

Having completed the measurement and principal calcu-

lations, I caused a large stone to be placed at each extremity of the base, to mark and perpetuate it for future occasions. The stone at the north end I inscribed with the following characters:

S. 3° 29′ W.
Yds.
11636.
T.
1788.

And that at the south end as follows:

N. 3° 29′. E
Yds.
11636.
T.
1788.

both inscriptions equally implying, that the opposite end of the base line lies in the direction therein expressed, distant 11636 English yards from the stone so inscribed.

It may be proper to record, that the north end of the base is on the sea beach, 27 yards from the surf; and 129 yards N. E. by E. easterly, from an old choultry in a Palmyra tope, called Namaswaumoodaly Choultry. From the mouth of Cuddalore river to the north end of the base I measured, with a perambulator, just four miles and one furlong.

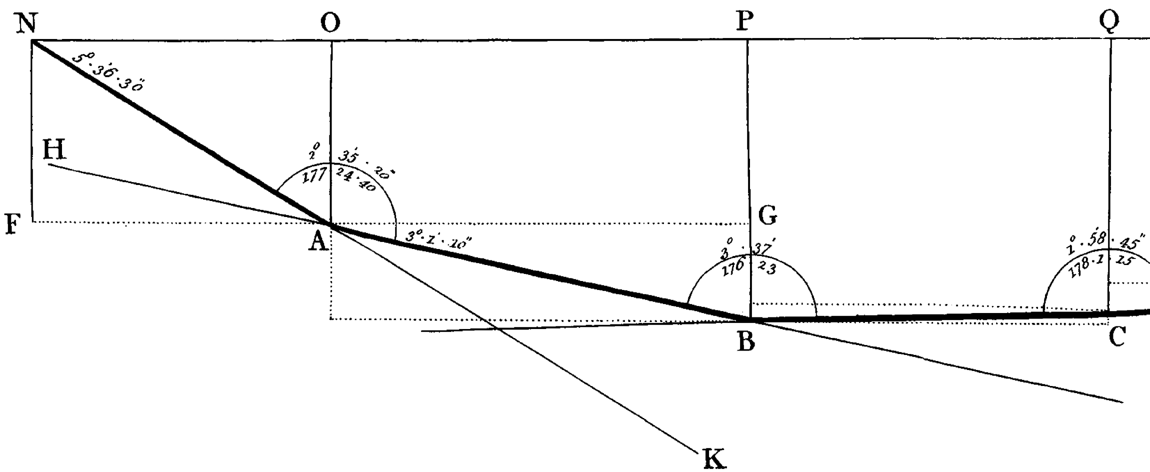
The south end of the base lies 42 yards from the surf, and 169 yards E. $\frac{1}{2}$ S. from a decayed choultry in a Palmyra tope, called Chinnachitty Choultry. There is another choultry and tope near the centre of the base; but the northern cluster

of trees before mentioned, is the first cluster we meet with, by the sea side, southward of Cuddalore river.

This measured base makes the exterior side of the thirty-third triangle of a concatenated series of oblique triangles, now carrying down the coast from the steeple of Fort Saint George.

Porto Novo,
10th June, 1788.

Fig. 1.



Scale 4000 Feet to an Inch

Fig. 2.

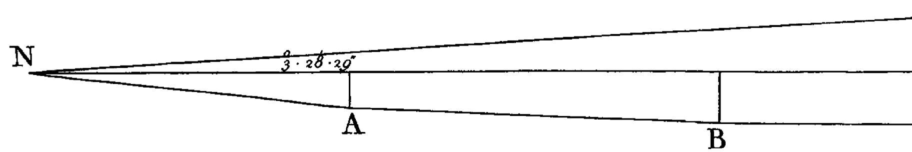


Fig. 1.

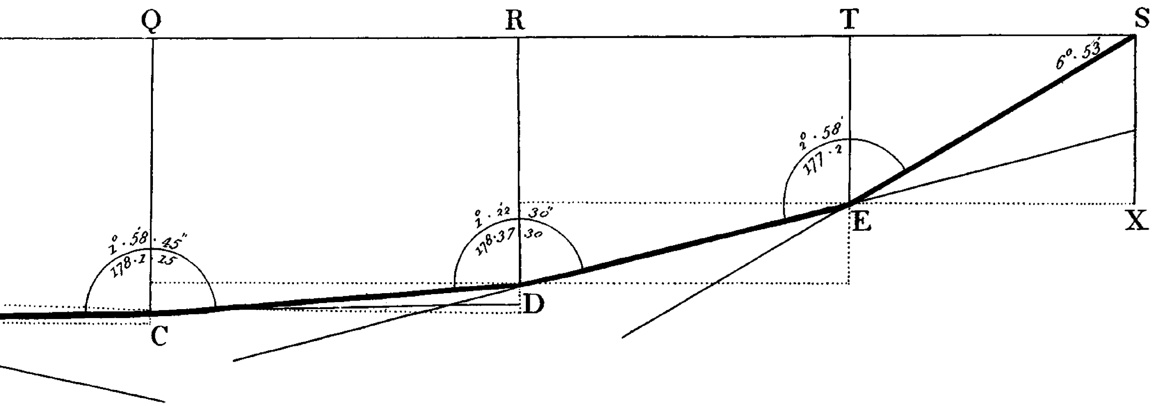
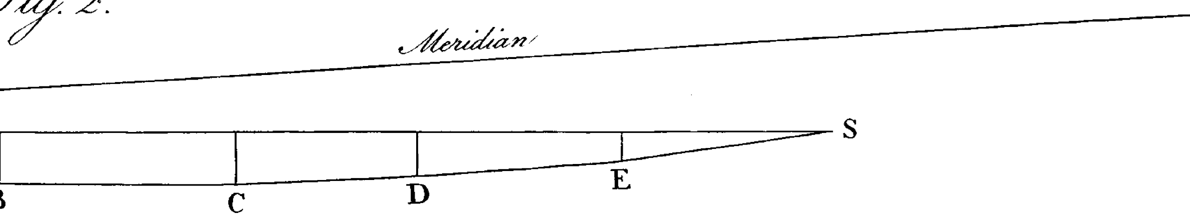


Fig. 2.



Basire sc.